SURVEYING FOR ARCHÆOLOGISTS.[1]

IV.

Simple Instruments for Measuring both Magnetic Azimuth and Altitude.

ALTHOUGH undoubtedly for final observations at any monument a theodolite must be employed, using the sun or a star in order to obtain astronomical or true bearings and so avoid all magnetic difficulties, and reversing the telescope to secure the correct altitude of the horizon; for rapid surveys there are many handy forms of instrument by means of which preliminary information can be gathered, both with regard to azimuth and, what is equally important, the angular height of the horizon.

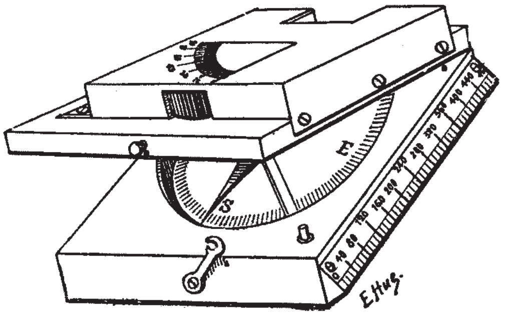

FIG. 13.—M. Hue's combined compass and clinometer.

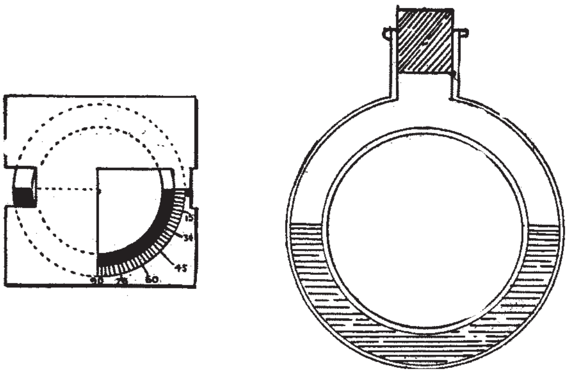

FIG. 14.—Details of the water-level clinometer.

It is quite certain that the use of the prismatic compass, in spite of its great convenience, must give way to other instruments which enable us to determine approximately the altitude of the horizon as well as the azimuth of any object the bearing of which we wish to obtain.

As a matter of fact there are now several such instruments available. They consist in the main of an azimuth compass, with an addition generally called a clinometer, enabling angles to be measured in a vertical plane. For this addition the first requisite, of course, is to be able to determine the true horizontal plane at the place of observation. This can be done by using a water level, a pendulum, or a properly adjusted bubble. I will give a brief description of three instruments which are based upon these various methods.

For the angular measurement of elevation, including, therefore, the angular height of the horizon as seen from any monument, the archæologist may use a very simple and convenient addition to the compass devised by M. Hue a distinguished French archæologist. He uses the water-level principle. The method employed can be readily gathered from the accompanying woodcuts, obligingly sent to me by the publishers of the "Manual of Prehistoric Researches," published by the Société préhistorique de France; a book which shows us, by the way, that the French archæologists are much more thorough and philosophical in their inquiries than their British brethren. It is not a question of the spade *versus* the theodolite, but of the spade *and* the theodolite, and as full instructions are given about one as about the other.

It is quite refreshing to read the chapter "Indications pour faire un levé de Terrain à la Boussole," and then the instructions given relating to subsequent work with the large-scale maps published by the French Government.

In Barker's instrument, called for short a clino-compass, we find the pendulum method employed. The altitude zero of the instrument is shown when the pendulum hangs vertically at rest. This is an addition to the azimuth compass, and can be used when the azimuth measures have been made by making the plane of the instrument vertical. The figure will show the method of use. The degrees of elevation can be read under the prism as well as by the pointer at the bottom.

In a reconnaissance lately among the Aberdeen circles I employed a clino-compass of Barker's pattern; it weighs only a few ounces and is carried in a sling over the shoulders; even a tripod can be dispensed with, though it is much better to have one; the lightest form is that supplied by the Kodak Company for their cameras, to which must be added an adapter at the top to fit the base and allow the instrument to be used horizontally and vertically. In this form, especially in the case of the altitudes, the mean of several observations should be taken. In my opinion, a desideratum for such work is a simple small instrument with level and reversible telescope for small

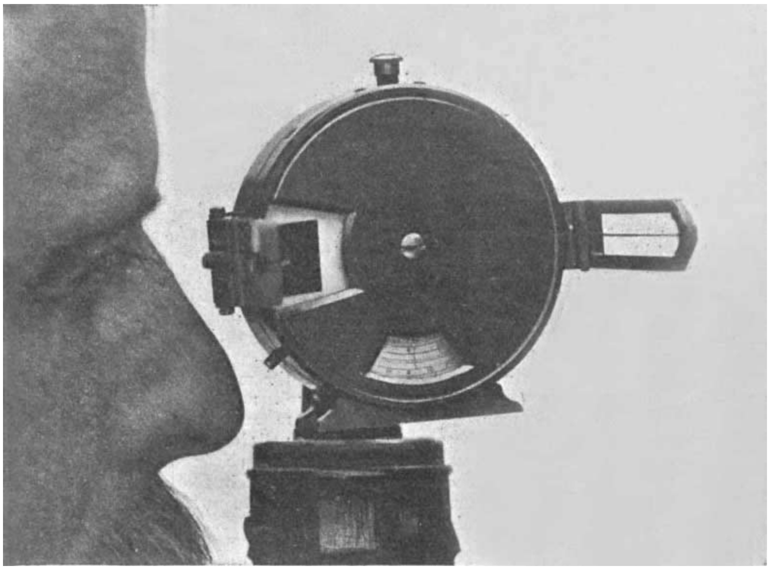

FIG. 15.—Vertical readings with Barker's clino-compass. An elevation of 3° indicated.

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[1] Continued from p. 511.

altitudes only—a miniature dumpy level, fitting on to the same tripod which carries a full-sized azimuth compass, reading to half-degrees.

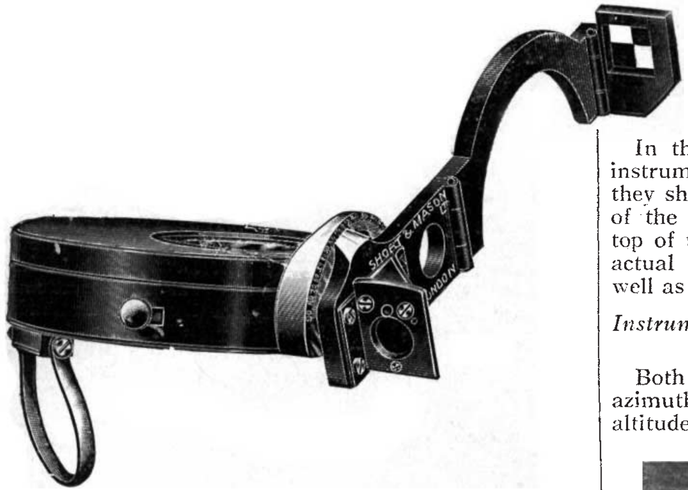

FIG. 16.—Verschoyle's pocket transit, showing the side arm for measurement of altitudes.

Azimuth and altitude are also provided for in the so-called Verschoyle pocket transit. In this the horizontal plane is provided for by adjusting a bubble in a short spirit level.

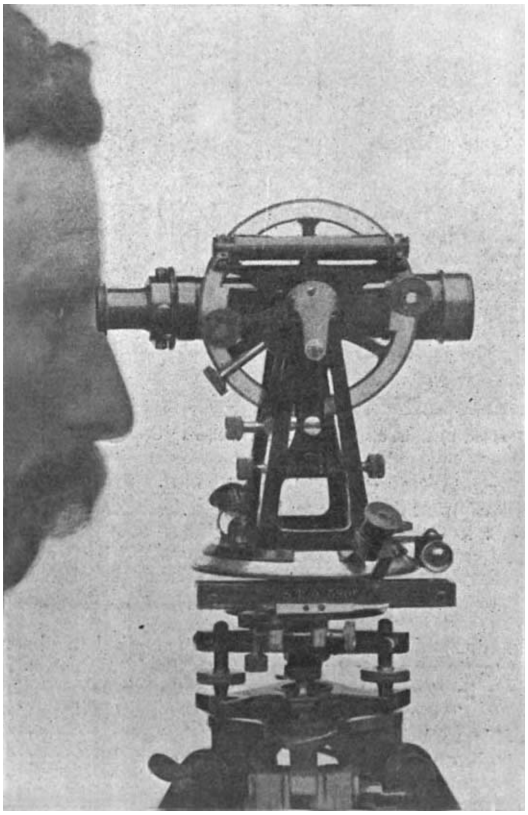

FIG. 17.—Observing an azimuth with a small theodolite.

The altitude arrangement is on the side of an azimuth compass, the graduations of which are read from the side by a right-angled prism, the graduations being cut on a bevelled edge.

Observations of magnetic azimuth and altitude can also be made by more complicated instruments, such as theodolites, miners' dials, &c., if, as is generally the case, a magnetic needle is provided for determining the magnetic north point.

The chief point about the theodolite in all its forms is that, whether provided with a needle to give magnetic north or not, observations of sun and stars can be made so that the true or astronomical north can be found.

In the readings of altitude made by any of these instruments, where trees, houses, &c., top the horizon, they should, of course, be neglected, and the elevation of the ground level at that spot taken. Should the top of the azimuth mark (stone, &c.) show above the actual horizon, its elevation should be recorded, as well as that of the horizon.

Instruments for determining Astronomical Azimuth and Altitude.

Both for the determination of astronomical or true azimuths directly, and for accurate observations of altitude, a theodolite is essential. It is true, as has been stated, that a theodolite armed with a magnetic needle can provide us with magnetic bearings, but if the best use is to be made of it the needle should be discarded altogether.

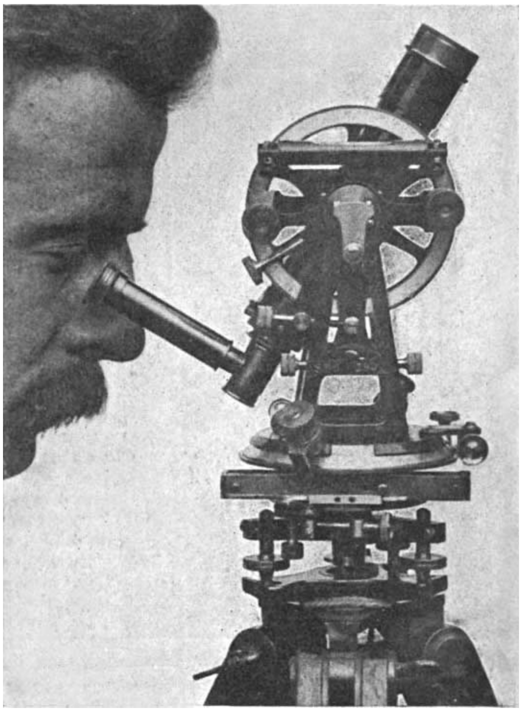

FIG. 18.—Eyepiece attachment to a theodolite to enable observation of the sun, or a star at a high altitude such as Polaris, to be made.

A theodolite is a very complicated instrument, and really little can be learned by a perusal of a description, however long or detailed. The best way of learning how to use it is to get a friend to give you instructions while you, *yourself*, take each part out of its box, set it up, and then proceed to make some observations with it.

In using a theodolite the various alignments required are referred to some fixed point on the horizon, or at all events some distance away, and the angles determined; the true azimuth of the fixed point is then found by observations of the sun or a star.

(1) If only an approximate azimuth is required, the best means of determining it is by fixing the direction of the sun or a star when it has the greatest altitude. This direction, of course, defines the astronomical meridian, as all heavenly bodies cross it when they are at their greatest altitude.

By using stars of both high and low altitudes a greater exactness can be obtained, but, after all, the method only gives a first approximation, as its weakness lies in the very slow change of altitude as the meridian is approached.

(2) A much more accurate method is that of observing the azimuth of a star when at the same altitude east and west of the meridian. If the mean of the two readings given by the azimuth circle be taken, the resulting reading indicates the direction of the meridian.

(3) To find the meridian line by means of the pole star is a simple and accurate method, as a value can be obtained at *any* time at night by a simple altitude, provided the time of observation is known.

Should there not be sufficient time to take the necessary observations, the true bearing of the sun and also some star can be obtained by inspection from Birdwood's azimuth tables.

If we employ the sun in place of a star, its change of declination during the interval between the observations must be taken into account.

It is not alone with regard to azimuth that the results obtained by a theodolite far surpass all others in accuracy, as all magnetic difficulties are overcome, and larger circles give us closer and more accurate readings.

In altitude observations the fact that the observing telescope can be reversed and swung round so that all sources of errors of the horizontal plane of the instrument can be eliminated is a matter of equal importance, for in such work, if accuracy is required, as it should be, one setting and one reading are of little use.

NORMAN LOCKYER.

THE HORNED DINOSAURS.[1]

FROM time to time mention has been made in the columns of NATURE of contributions to our knowledge of what are perhaps the most wonderful members of a wonderful order, namely, the horned dinosaurs, or Ceratopsia, of the American Upper Cretaceous, the last of such notices relating to Mr. Lull's conclusions to be drawn with regard to the cranial muscles of the typical forms from the study of the skull. In the present sumptuously illustrated volume, which has a melancholy interest as being mainly the work of an exceedingly talented and promising palæontologist who did not live to earn the full reward of his labours, we have a full description of all that is known with regard to the osteology, relationships, and classification of these wondrous reptiles, together with notes and speculations (by Mr. Lull) regarding their distribution, phylogeny, and probable habits and environment.

Restoration of a Horned Dinosaur (Triceratops), with an Iguanodont (Trachodon) in the distance. From Hatcher's "Ceratopsia."

In his preface Mr. Hatcher, we are glad to observe, bore testimony to what we owe to the late Prof. O. C. Marsh in the matter of our knowledge of the Ceratopsia. To a large extent his generosity "made it possible to bring together the collections upon which this volume is based. Nor did his contributions to the subject end here, for, as appears on the title-page, the present memoir was based on his preliminary studies, and although he left no manuscript aside from his

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[1] "The Ceratopsia." By J. B. Hatcher. Edited and completed by, R. S. Lull. Pp. xxx+300; plates i-lii. (Washington: U.S. Geol. Survey, Monograph xlix., 1907.)